The RCRA Subtitle C prevention program addresses many environmental and human health effects that involve long time horizons due to factors such as the slow movement of groundwater or the persistence of contaminants associated with health effects. As a result, an assessment of the benefits of RCRA must consider the avoided damages that would have continued indefinitely into the future, creating health effects or requiring averting behaviors many years from the present time.[1] For example, avoided groundwater contamination is likely to be a key outcome of RCRA's land disposal restrictions. While many potable aquifers are not currently used for drinking water and therefore have no "use value" today, it is difficult to predict the long-term demand for these resources or the long-term value associated with protecting them from contamination. Despite the uncertainty involved in assessing long-term effects, it is important to identify and discuss these potential benefits in any comprehensive program evaluation of RCRA. This chapter addresses long-term benefits that are not captured in the benefits approaches outlined in Chapters 2 and 3.

Some aspects of long-term benefits (e.g., the number of cancer cases avoided) can be estimated through modeling. However, there is little consensus in the economics literature on assigning monetary values to the health effects and costs assumed (or avoided) by future generations.[2] Moreover, some benefits may occur far in the future, or may increase over long time horizons due to factors such as increased population density (which could increase exposure to

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[1] Long-term benefits are related to the concept of sustainability, which measures the extent to which present actions preserve for future generations the level of environmental resources and quality that are available today. Sustainability incorporates long-term benefits and a broader "polluter pays" principle that requires those using resources or causing environmental damage to be responsible for assuring that damages will be repaired and resources replenished. Other aspects of sustainability and the polluter pays principle are addressed in our Chapter 6 discussions of inter-generational equity.

[2] EPA's *Guidelines for Economic Analysis* (Chapter 6) discusses the difficulties related to social discounting for inter-generational policies.

health risks). This chapter discusses four distinct aspects of potential long-term benefits. The first three methods address potential long-term impacts of RCRA Subtitle C regulation:

- **Avoided long-term damages,** reflecting the continuation of health and ecological benefits into future generations.

- **Avoided increases in damages** due to changes in affected populations (e.g., future population growth that results in a higher number of people affected) and/or increases in costs of clean water and land.[3]

- **Avoided damage from unforeseen events or issues** such as environmental damages caused by substances whose risks are poorly understood today.

While these three types of long-term benefits represent regulatory impacts that are theoretically quantifiable (though perhaps not with currently available information), it is difficult to estimate their value because economic theory cannot predict the value that future generations will place on environmental goods. Increases (or decreases) in the value of environmental quality and resources would affect the value of all long-term benefits. We therefore address this fourth issue separately, and provide a separate method for characterizing potential changes in future generations' value of environmental quality.[4] All of our methods focus on qualitative discussions, but we also identify quantitative analyses that may help illustrate the potential magnitude of benefits.

In addition to long-term benefits directly associated with avoiding contamination, the RCRA Subtitle C program may also contribute to two other long-term impacts: long-term changes in behavior related to management of waste, and long term impacts related to waste minimization programs. Long-term behavior changes include behaviors directly mandated by regulation (e.g., improved technical specifications) and behaviors that appear to be indirectly related to specific programs (e.g., an increased demand on the part of property purchasers and banks for "clean" properties as a condition of sale).[5] Waste minimization benefits, in contrast, are related to improved production efficiency and would be reflected in future reductions in waste management and disposal

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[3] In addition to population growth, increases in costs of clean resources may also be associated with other factors such as decreased availability of potable water due to water scarcity.

[4] Recent literature suggests that the willingness to pay for environmental quality has increased and changed in focus in recent decades. One discussion of the transformation in resource values is *Forest Dreams, Forest Nightmares: The Paradox of Old Growth in the Inland West*, by Nancy Langston and William Cronon (University of Washington Press: October 1995).

[5] The increased demand for clean properties is likely attributable (at least in part) to the combination of regulations and liabilities established under both RCRA and CERCLA.

costs. Although these changes in behavior or cost reductions may ultimately be associated with benefits, we discuss these attributes in Chapter 7 as Program Context Attributes because it is often impossible to determine either the net "value" or the causality associated with changes in behavior, and to predict long-term changes in cost attributable to the Waste Minization program.

4.1 AVOIDED DAMAGES OVER LONG TIME PERIODS

RCRA regulations prevent the release of constituents that could persist in soil or groundwater and cause human health and ecological impacts for several generations. In Chapter 3 we identified the methods for estimating the value to the current generation of preventing those effects. Our proposed methods for estimating the potential continuation of (avoided) damages over long time horizons include two separate analyses; a general discussion of the continuation and accumulation of (avoided) damages over time, and a specific analysis of the avoided contamination of groundwater resources, measured as the volume of groundwater contamination avoided.

4.1.1 *General Qualitative Discussion of Long-Term Damages*

We propose a qualitative discussion of the potential accumulation of benefits associated with long-term damages (e.g., avoided costs, property value benefits) and factors potentially influencing benefits such as natural attenuation of contamination and changes in property values over time. This method is consistent with Approach A and also with any of the modeling approaches. Note that the pathway modeling approaches would provide a range of quantified benefits that would reflect different modeling scenarios and time horizons; the qualitative discussion of long-term damages would provide context for the interpretation of these modeling results.[6]

4.1.2 *Method for Identifying Groundwater Conservation Benefits*

The RCRA program prevents long-term damage to groundwater resources by establishing rigorous standards for waste disposal, including such requirements as the Land Disposal Restrictions (LDRs) which restrict certain waste streams to specific, low-risk disposal methods or establish constituent concentrations that must be met before waste can be disposed. The program aims to prevent damaging releases to the environment, including groundwater. Groundwater damage from a single release may increase over decades or even centuries. As a result, groundwater protection

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[6] Consistent with EPA's *Guidelines for Economic Analysis,* we suggest a range of scenarios that would provide both discounted and undiscounted estimates for avoided costs, and a quantification of health effects that does not apply values or discount rates.

is an important part of the potential long-term benefits of the program.[7] To identify the total extent of groundwater preserved under RCRA, we provide the following approach:

- **Step 1.** Identify the number of groundwater contamination incidents avoided by RCRA. In Approach A this is possible by using Superfund, Corrective Action, and state data to calculate the percentage of hazardous waste sites that require groundwater remediation, and then multiplying that percentage by the number of avoided hazardous waste sites identified in Approach A. In Approaches B, C, and D, incremental contamination can be identified using modeling results and the same extrapolation to avoided hazardous waste sites.

- **Step 2.** Identify average extent of groundwater contamination in cubic feet or gallons and apply to the avoided sites. Again, in Approach A this value can be an average based on typical Superfund, Corrective Action, and state sites. For Approaches B, C, or D, this extent can be modeled directly.

This calculation provides an initial estimate of the quantity of groundwater spared from contamination by RCRA. However, this estimate may be high if considerable contamination of groundwater already exists from non-RCRA sources, and additional "without-RCRA" contamination would not increase the cost of remediation. Therefore, we would also provide a second, lower estimate that includes a simple correction for existing contamination. The lower estimate would adjust the total quantity of groundwater by subtracting the percentage of groundwater resources believed to be contaminated by other sources.[8]

These approaches would provide a first cut on characterizing long-term benefits due to the inter-generational duration of damages. It would, however, be associated with significant uncertainty because it would require assumptions about future waste generation and management practices, the duration of contamination events, and the likelihood that remediation would occur.[9]

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[7] Our Chapter 3 benefits methods address the avoided costs of obtaining alternative water supplies. Avoided costs of alternative water supplies reflect a portion of the use value of groundwater, but do not address "non-use value" (i.e., the value to the current generation of preserving clean groundwater that is not used for drinking). While these values may be important, there is no currently accepted method for identifying non-use values associated with groundwater.

[8] We have not yet identified a single data source that identifies the current extent of groundwater contamination. However, a number of studies have been performed estimating the extent of groundwater contamination due to petroleum leaks from underground storage tanks (USTs). Estimates from this literature could be used as a proxy for total contamination.

[9] One issue in characterizing potential long-term benefits is the degree to which natural processes such as biodegradation may reduce the prevalence of some contaminants over time, since

4.2 AVOIDED INCREASES IN DAMAGES RELATED TO CHANGES IN AFFECTED POPULATIONS

In addition to continuing over long periods of time, future damages in the absence of RCRA might also increase due to changes in the density of affected populations. To characterize long-term benefits associated with avoiding increases in future damages, we would provide a qualitative discussion of factors that might drive these increases (e.g., population growth, scarcity of resources due to contamination, changes in the legal framework guiding resource utilization). In conjunction with any of the three modeling approaches, we would also conduct sensitivity analyses to identify the human health impacts related to higher population densities near pre-RCRA facilities.[10] In addition, we would conduct a sensitivity analysis to characterize the potential increases in water prices (i.e., as a result of scarcity and contamination).

These analyses would provide a rough estimate of the magnitude of benefits that might be associated with potential increases in exposure in a without-RCRA scenario. In addition to factors of uncertainty discussed above, projections of future population densities and use of drinking water would be uncertain.

4.3 THE PRECAUTIONARY PRINCIPLE: PROTECTION AGAINST UNFORESEEN ISSUES OR EVENTS

The RCRA Subtitle C program may yield benefits associated with the reduction of currently unknown or underestimated risks. In other words, RCRA's engineering standards for disposal units may prevent not only known hazards, but also the release of constituents that are identified as hazardous in the future. In this way the program may provide "insurance" against future damages.[11]

The "precautionary principle," which describes a preference of implementing protective policies or regulations in advance of conclusive scientific evidence that connects activities (or

natural attenuation might potentially off-set long-term damages. Various natural processes may either "remove" contamination or may limit the spatial extent of environmental damage. Because RCRA addresses a wide variety of contaminants and exposure pathways, it would be extremely difficult to estimate the effects of natural attentuation, but it is likely that damages would not increase in a simple linear pattern over long periods of time.

[10] This would be done by applying a reasonable range of future population densities to the model and assessing increases in the number of people potentially affected.

[11] RCRA can also create an analogous risk tradeoff by encouraging use of untried chemicals as replacements for regulated ones; this substitution risk tradeoff can be identified in using the methodology outlined in Option 2.

chemicals) to risk, has recently emerged as a principle in international environmental policy.[12] While both the definition and practical implementation of a precautionary principle is still a matter of considerable debate, the essential wisdom of precaution is reflected in the notion that "an ounce of prevention is worth a pound of cure." While we do not attempt to resolve the issues surrounding the development and use of precautionary policies, this principle is consistent with the preventative objectives of the RCRA Subtitle C program. Subtitle C regulations have designated as hazardous some wastes that contain constituents with unknown potential risks. Some of these constituents have later been found to be hazardous; prior to their designation, however, RCRA's protective disposal requirements (e.g., liners) have prevented releases.[13] It is possible that the strict disposal regulations of RCRA will reduce or prevent exposure to hazards that have not yet been identified or verified; the avoided exposure would ultimately be a measurable benefit of the program.

It is clearly impossible to identify "unknown effects" *a priori*, but an examination of "hindsight" might be an appropriate way to characterize these benefits. In addition, RCRA may already have provided an identifiable short-term "precautionary benefit" among its own waste regulations and listings. We suggest two possible approaches to characterising the potential benefits related to the precautionary aspects of RCRA:

- **Option 1: Examine the extent of existing compliance with new RCRA listings.** Using data from RIAs for RCRA wastes listed since 1980, identify in each new listing RIA the number of affected facilities that were already in compliance with the new rules as a result of earlier waste treatment investments under RCRA. Where previous RCRA regulations result in management practices that were properly addressing "new wastes," these regulations provide "insurance." One immediate benefit of this insurance is the avoided costs of incremental compliance enjoyed by the facilities that were already protective under earlier regulations.[14] However, this estimate

[12] There is a large body of theoretical literature discussing the development and implementation of versions of the precautionary principle. Treaties articulating the precautionary approach include the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer, the 1992 Convention on Biological Diversity, the 1992 Treaty on European Union, and the 1992 Rio Declaration on Environment and Development, which states "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."

[13] RCRA's delisting process also supports the notion of precaution in recognizing that emerging research may determine that certain wastes and constituents do *not* pose significant risks.

[14] An issue with this estimate is the extent to which a facility "over-complied" with initial regulations in anticipation of additional regulations, or in response to state standards. While these

does not address total "insurance" benefits and should be considered only as an indicator in a qualitative discussion.

- **Option 2: Identify historical examples of underestimated risks.** Identify one or more examples of a hazardous waste (e.g., lead) that was widely considered to be less toxic than it is today. Identify the extent to which RCRA addresses this waste as part of otherwise regulated waste streams. For example, include the quantities of lead disposed of as part of industrial waste streams, but do not include lead used in gasoline or paint. Identify potential damage or risk associated with the avoided quantities; this illustrates potential damages avoided by RCRA. However, like Option 1, it is not a comprehensive measure of avoided damage and should be used for illustration only in a qualitative discussion.

Neither of these approaches provides a comprehensive estimate of future damage avoided by RCRA; both instead provide an estimate of the extent to which existing regulations did or could address newly identified problems. If these methodologies indicate a considerable benefit, then additional efforts to refine these estimates may be a reasonable next step.

Exhibit B-5 in Appendix B contains a summary description of our proposed methods for addressing long-term benefits, including a brief description of data requirements for each.

4.4 BENEFITS FROM LONG-TERM INCREASES IN THE VALUE OF ENVIRONMENTAL QUALITY

Long-term benefits present a theoretical "problem" in economics. Traditional economics discounts future benefits and costs to account for market growth and the expected return on an investment in today's market. However, the economic preferences of future generations (and therefore the economic value of resources in future generations) are essentially unknowable. Economic measures may therefore be unable to predict **increases** in resource value as a result of scarcity (see above) or of changes in social norms. One example of dramatic change in the social value of a resource is the change over the past century in the American view of forests, which have evolved from a resource for timber with relatively little value to a resource for recreation and non-use habitat that can far exceed the value of the fiber source.[15] This evolution in value could not have been predicted by traditional economics, which can only reflect the value that current generations

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issues may be addressed by examining contemporary literature on patterns of environmental investment and on the extent and anticipation of environmental regulations; we suggest that these issues be addressed only if the initial benefits estimate is substantial enough to warrant the effort.

[15] See Langston and Cronon (1995).

place on resources. Furthermore, the value placed on environmental protection (i.e., avoiding risk) may itself grow if future generations become more risk averse.

Conversely, a resource that is highly valued today may not maintain its value in the future if substitutes emerge or preferences change. There is a fundamental difficulty in predicting how, if at all, a future flow of resources will be valued. New research in this area may be revealing, and may propose additional methodologies for adjusting discussions of future benefits to reflect a range of economic growth and scarcity scenarios as well as potential shifts in social value.

Our proposed method for characterizing the effects of changes in risk aversion and valuation of environmental quality by future generations would involve two steps:

- **Qualitative discussion of past trends** of risk aversion and valuation of environmental goods. Our discussion would include an assessment of historic decreases in acceptable risk over time and concurrent increases in the valuation of environmental goods. We would then provide a discussion of how these trends might change in the future, and identify the potential implications for values associated with clean resources. In addition, we would provide a discussion of potential changes in willingness to pay for resource utilization (i.e., use values) that could, for example, be associated with changes in recreational behavior (e.g., increases in the amount of time for recreational activities available to individuals).

- **Discussion of potential effects on value of groundwater.** Using recent literature and the estimates of avoided groundwater contamination developed in the modeling approaches, we would discuss the potential impacts of changes in value on the avoided groundwater contamination benefits of RCRA. While some portion of the value of groundwater is reflected in the cost of obtaining alternative water supplies (captured in the avoided costs attribute in Chapter 3), changes in the way people regard groundwater (i.e., as an important ecological resource or as an option for future use) may have an important impact on the value of the RCRA program.

This analysis would provide an overview of the potential magnitude of the impacts that future generations' changes in value might have on all of the long-term benefits associated with RCRA. We recognize that this discussion would be qualitative and would not capture the possibility of future changes in trends related to risk aversion and the valuation of environmental quality. However, the perspective of future generations forms a central issue in the discussion of long-term benefits, and it is essential to, at a minimum, discuss the potential implications of evolution in values.